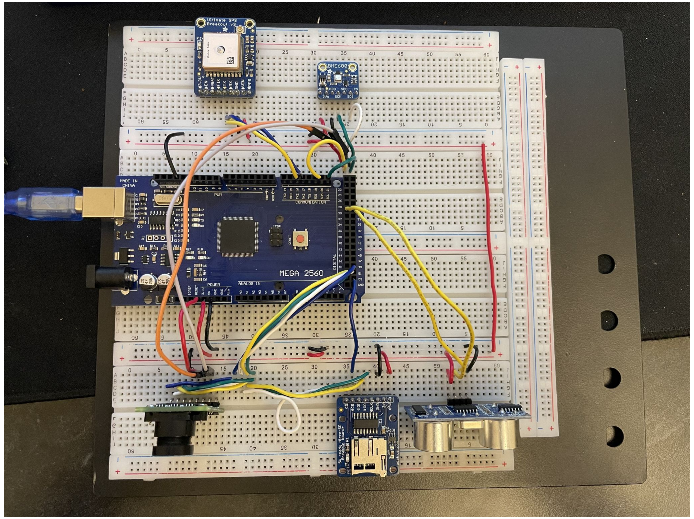
Group 1
WCR Beetle Data Analysis

Ayush, Jeremy, Pavan, Sam

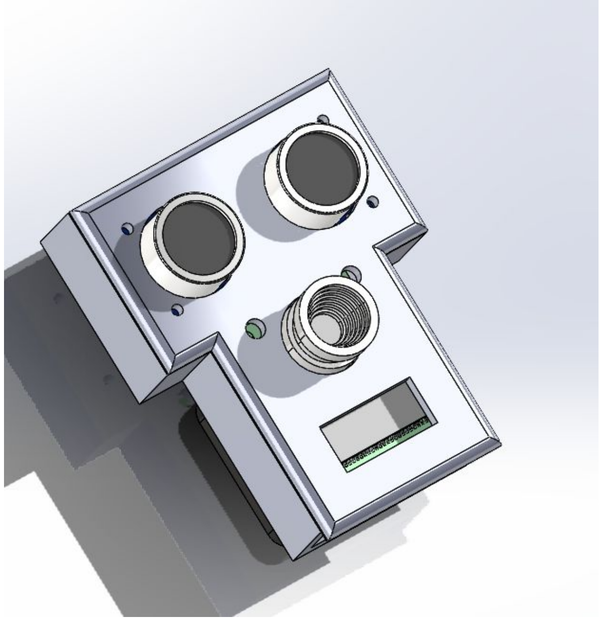
Development on Hardware

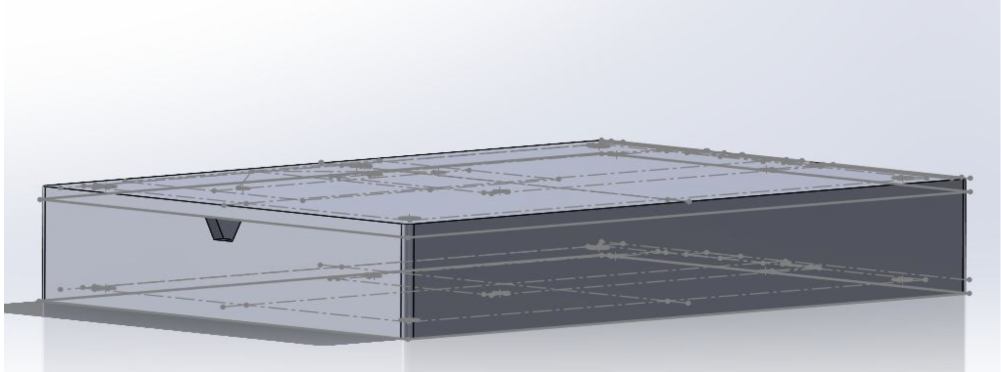
Hardware:

- Arduino MEGA2560 (replaced the arduino Nano)
- Arducam mini 2mp plus
- 5V microSD breakout module
- HC-SR04 Ultrasonic sensor
- BME680
- Ultimate GPS Module
- ~~DS3231 RTC~~



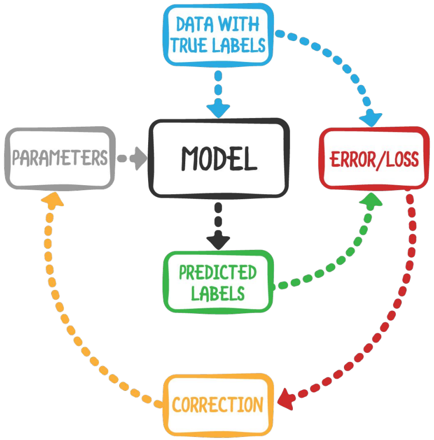
CAD Model



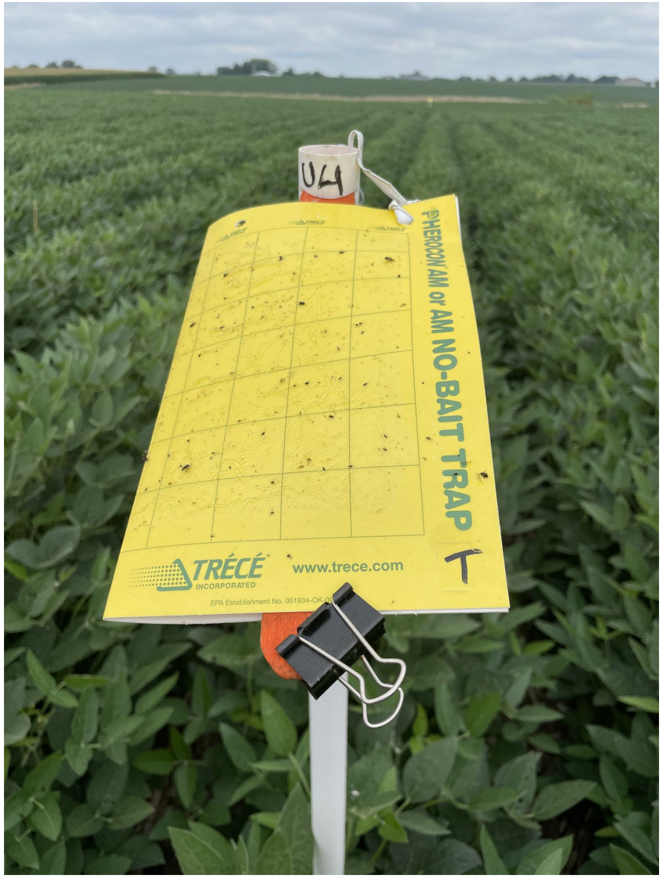


Training

- Load data through the dataloader
- Model makes a random prediction based on randomly initialized parameters
- Optimizer calculates the gradient based on expected classification and actual probabilities
- Automatically updates parameters
- Repeat



Initial Data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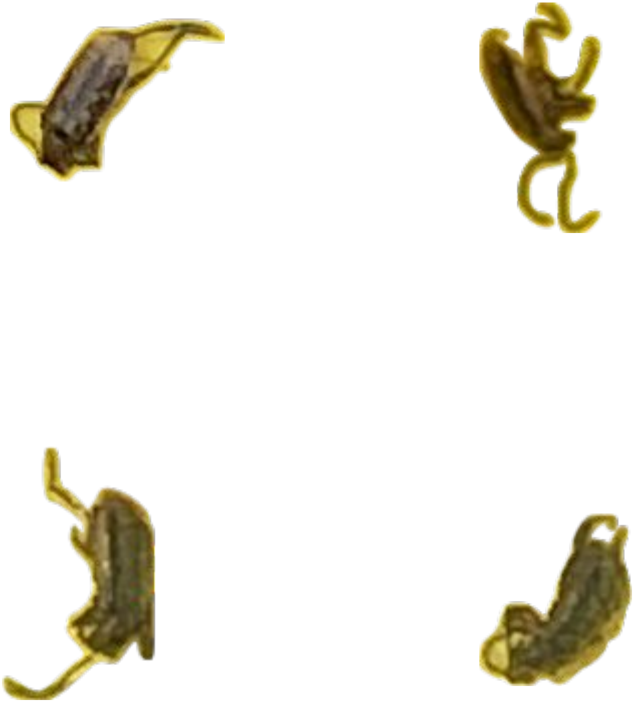
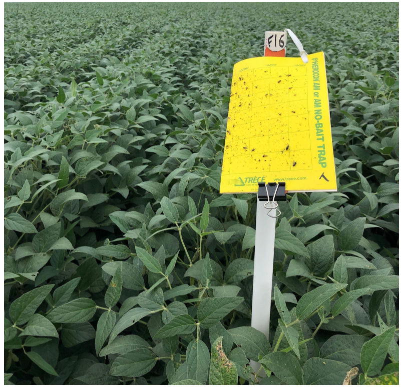


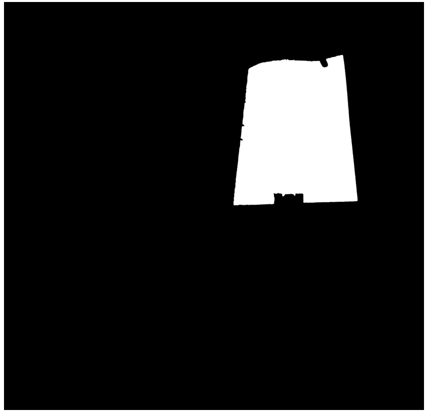
Dataloader

Dataloader

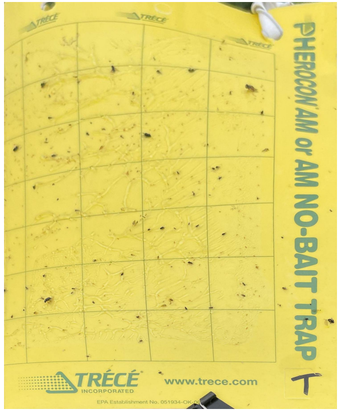
- Real Dataset and Issues
  - Lack of data
  - Lots of “noise”
- Dataloader
  - Crop Image
  - Paste beetles
  - Record beetle location in .txt file
    - class_id, center_x, center_y, width, and height



Stage 1



Stage 2

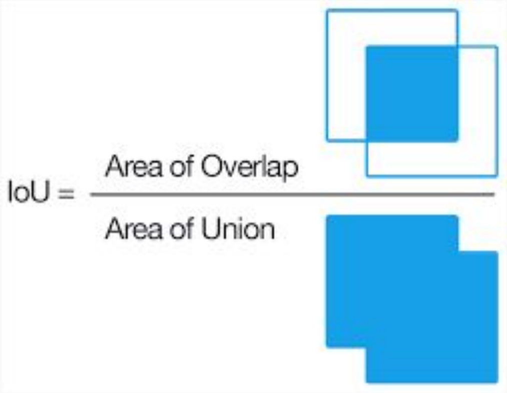


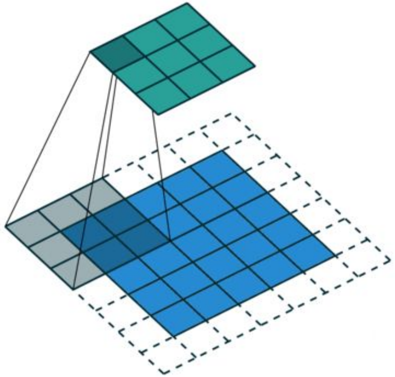
Stage 3

Model Description

Machine Learning Terminology

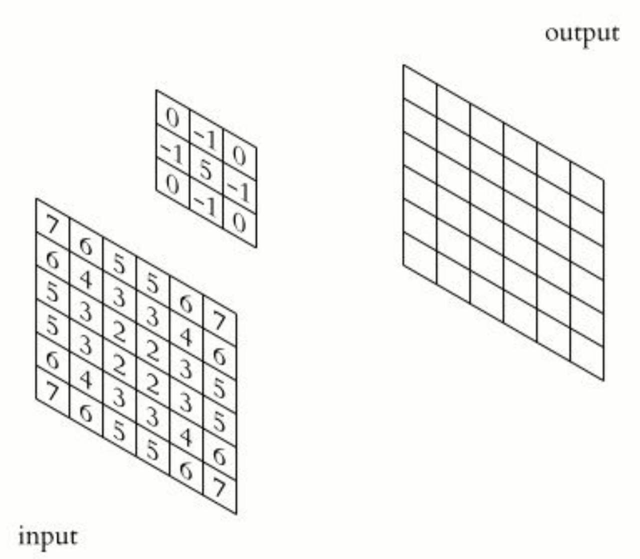
- Intersection over Union (IoU)
  - Quantifies degree of overlap between two regions
- Precision
  - Proportion of predicted positives that were correct
- Recall
  - Proportion of actual positives that were predicted correctly
- Average Precision
  - Area under precision-recall curve, calculated class-wise
- mean Average Precision (mAP)





Convolutional Neural Networks

- Specialized type of neural network designed to recognize patterns in visual data like images, videos, and animations.
- It preserves **spatial information** of an image by using filters that scan across the input image.
- Detects features like: Edges, shapes, and colors
- Can detect features regardless of location, orientation, distortion.



0	-1	0
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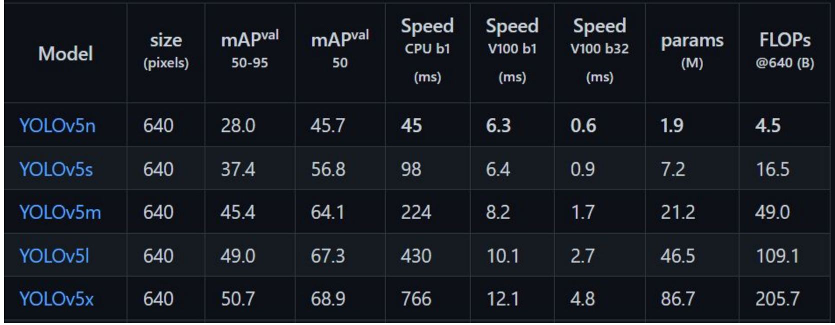
0	-1	0

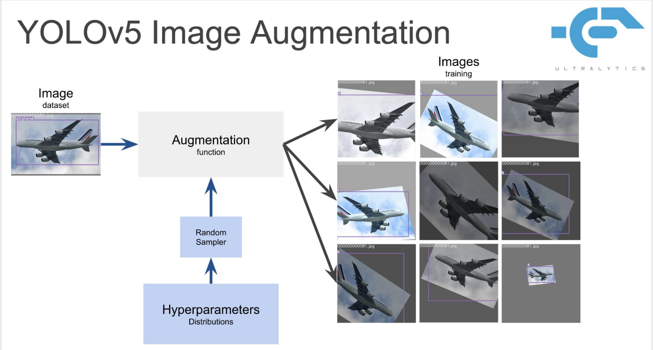
7	6	5	5	6	7
6	4	3	3	4	6
5	3	2	2	3	5
5	3	2	2	3	5
6	4	3	3	4	6
7	6	5	5	6	7

YOLOv5

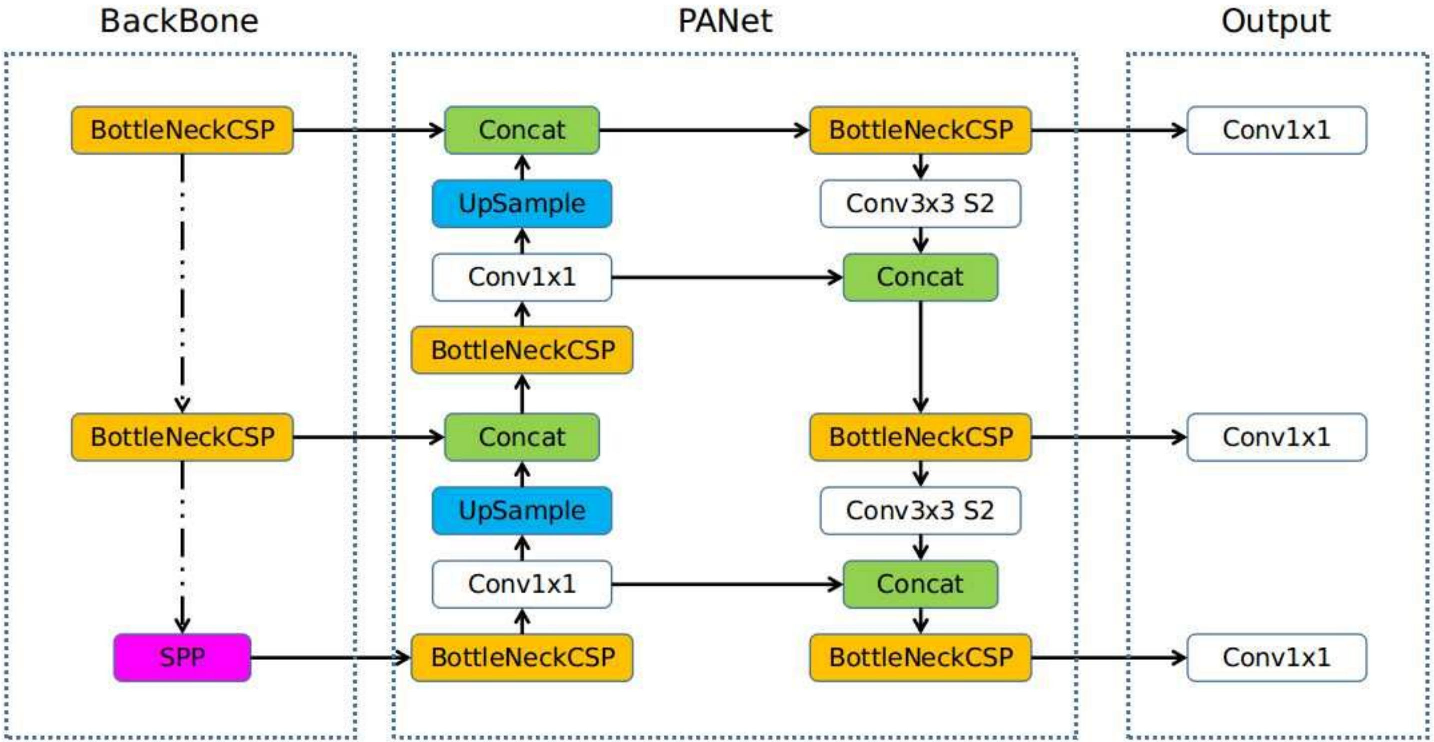


Model	size (pixels)	mAP^{val} 50-95	mAP^{val} 50	Speed CPU b1 (ms)	Speed V100 b1 (ms)	Speed V100 b32 (ms)	params (M)	FLOPs @640 (B)
YOLOv5n	640	28.0	45.7	**45**	**6.3**	**0.6**	**1.9**	**4.5**
YOLOv5s	640	37.4	56.8	98	6.4	0.9	7.2	16.5
YOLOv5m	640	45.4	64.1	224	8.2	1.7	21.2	49.0
YOLOv5l	640	49.0	67.3	430	10.1	2.7	46.5	109.1
YOLOv5x	640	50.7	68.9	766	12.1	4.8	86.7	205.7

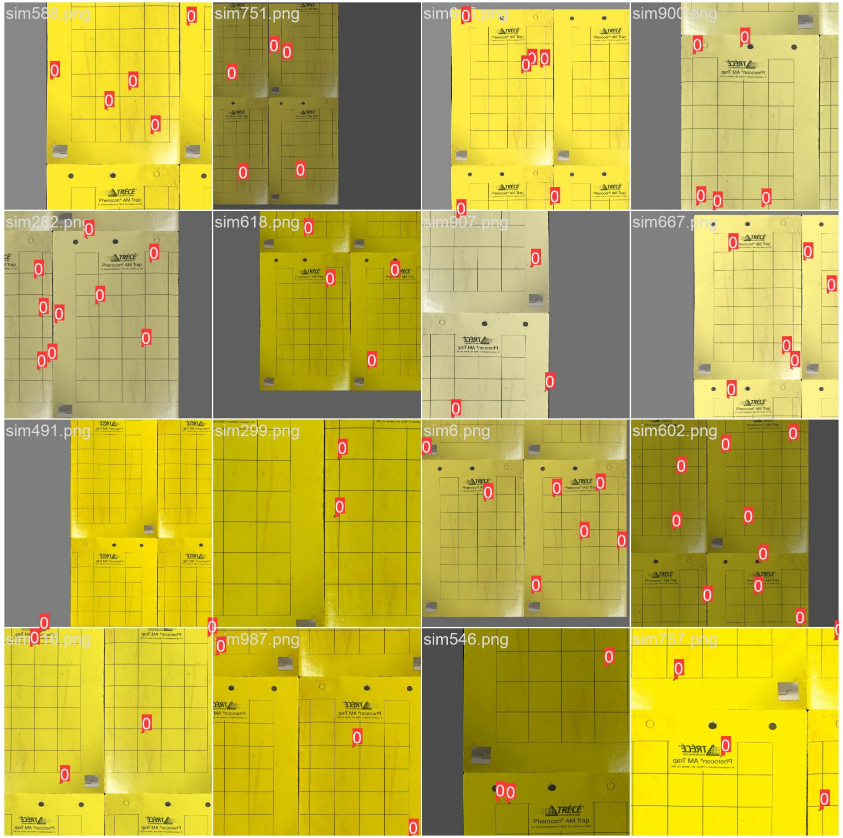
- ~250 images, 41 beetles
- 80-20 train-test split
- Excellent computer vision AI for object detection and image classification
- Using YOLOv5m to ensure accuracy, then we can scale down
- Data augmentation methods:
  - RandomPerspective
  - Mosaic
  - Vertical/Horizontal Flip
- Outputs bounding box location and confidence



Overview of YOLOv5



Results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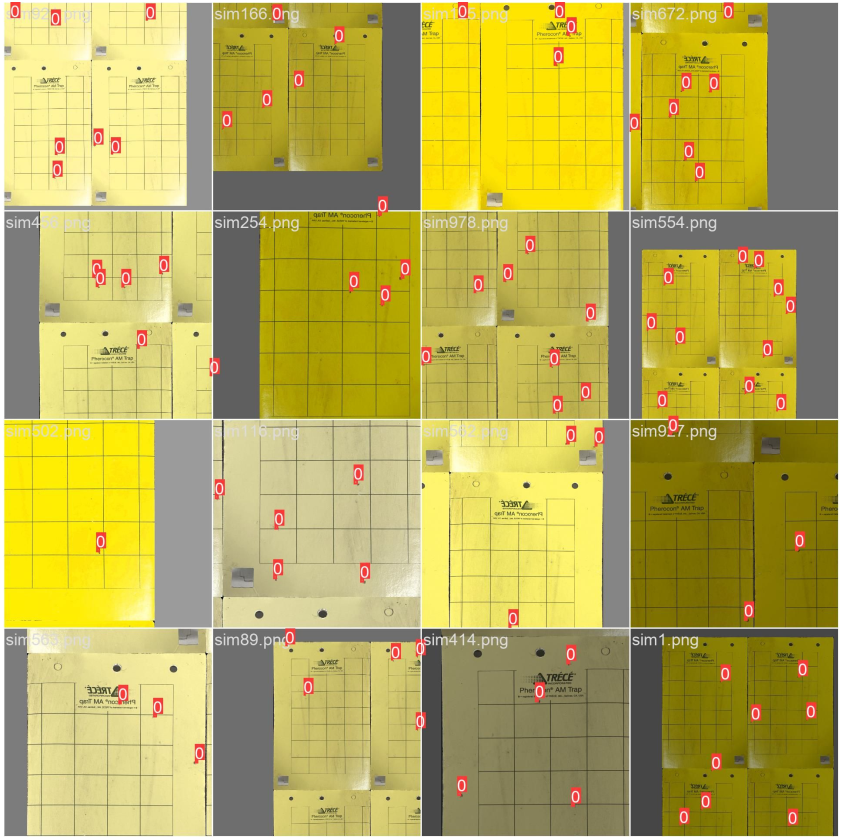
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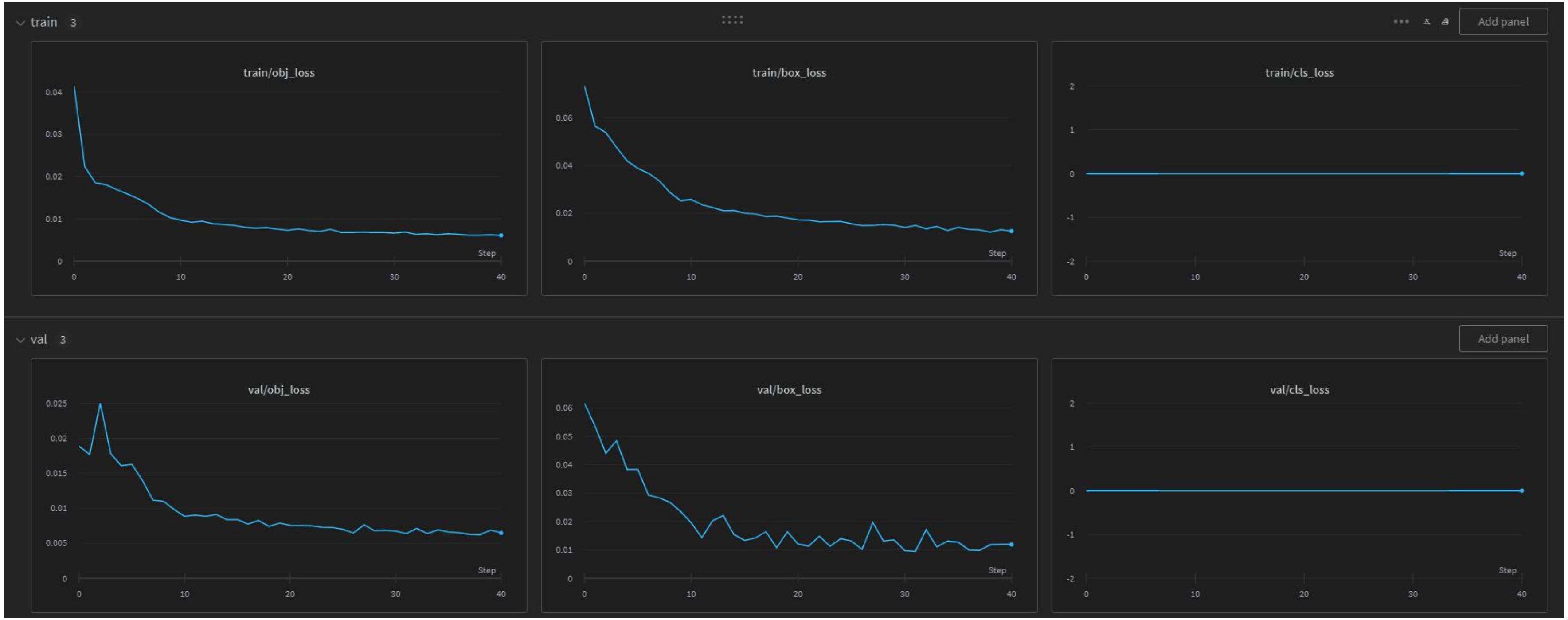
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Add panel
train/obj_loss
0.04
0.03
0.02
0.01
0
0
10
20
30
40
Step
train/box_loss
0.06
0.04
0.02
0
0
10
20
30
40
Step
train/cls_loss
2
1
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-1
-2
0
10
20
30
40
Step
val 3
Add panel
val/obj_loss
0.025
0.02
0.015
0.01
0.005
0
0
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20
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Step
val/box_loss
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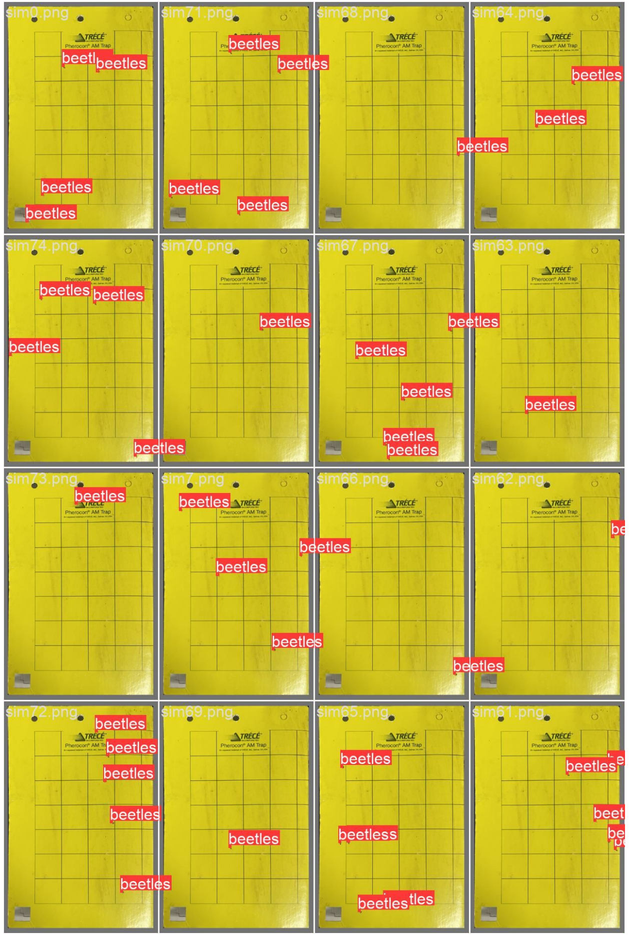
Step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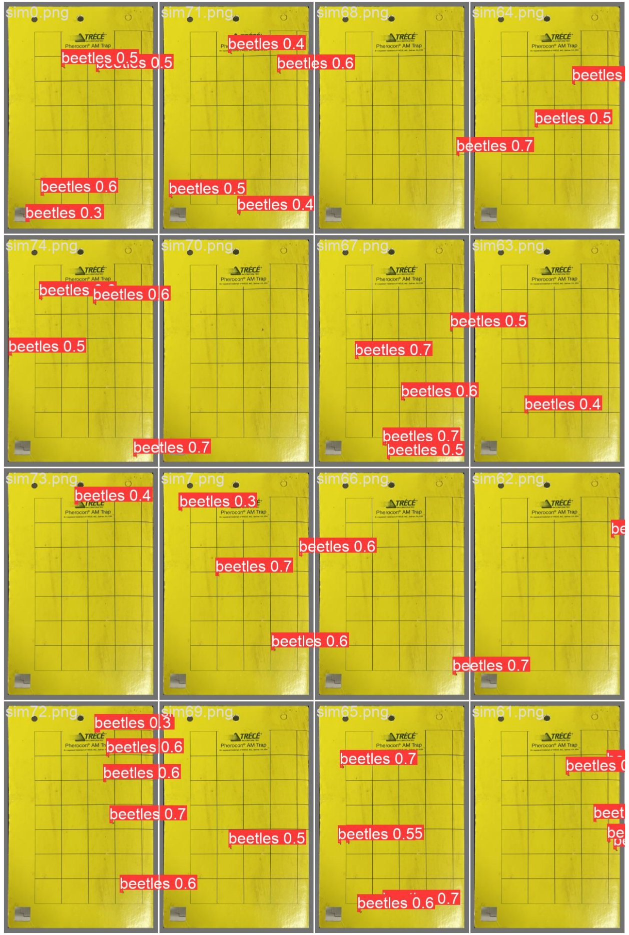
beetles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beetles 0.3
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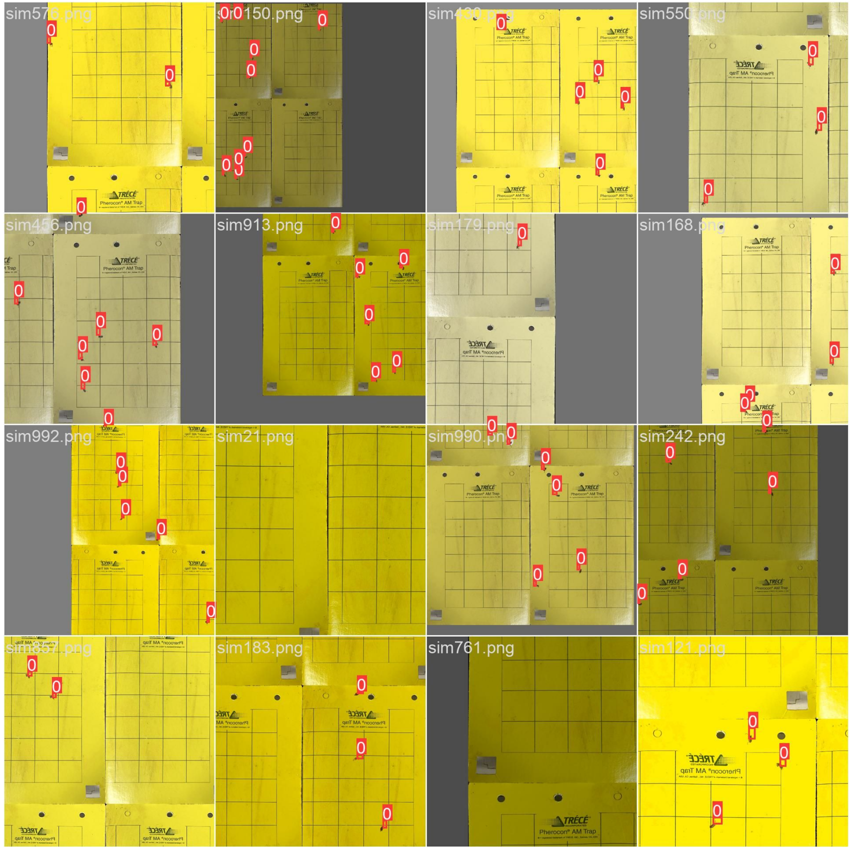
beetles 0.55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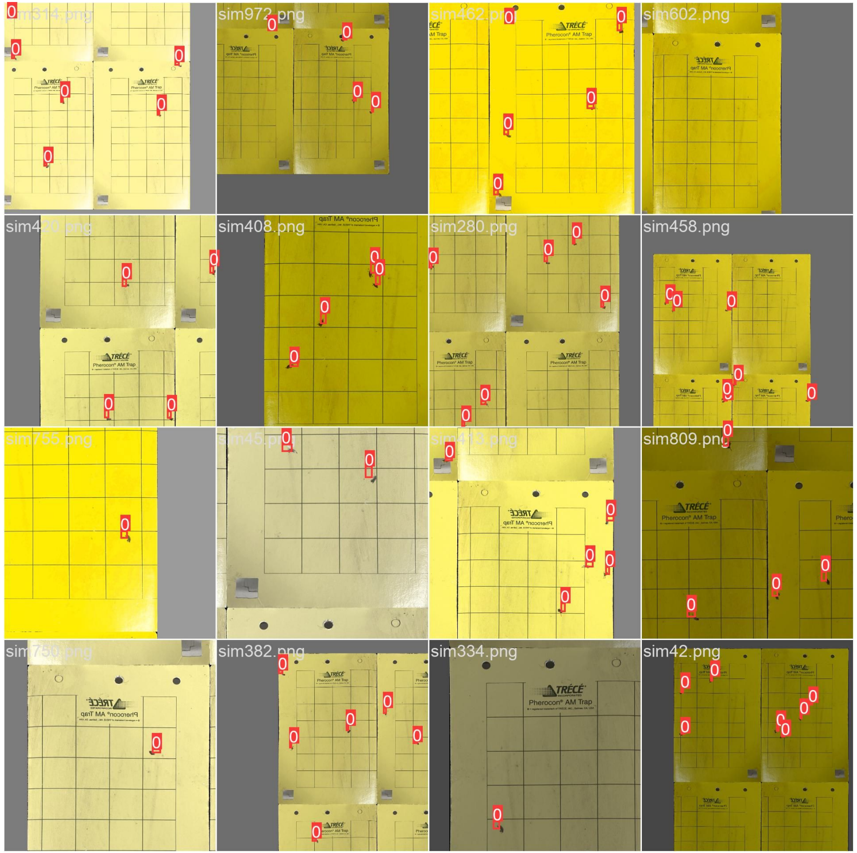
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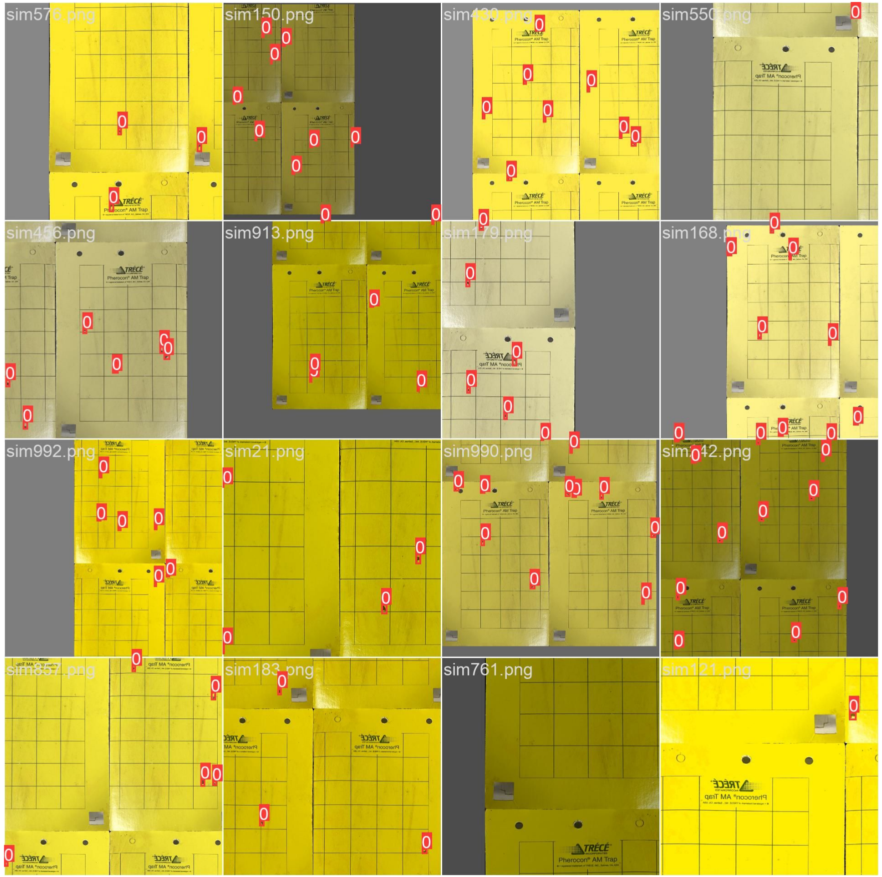
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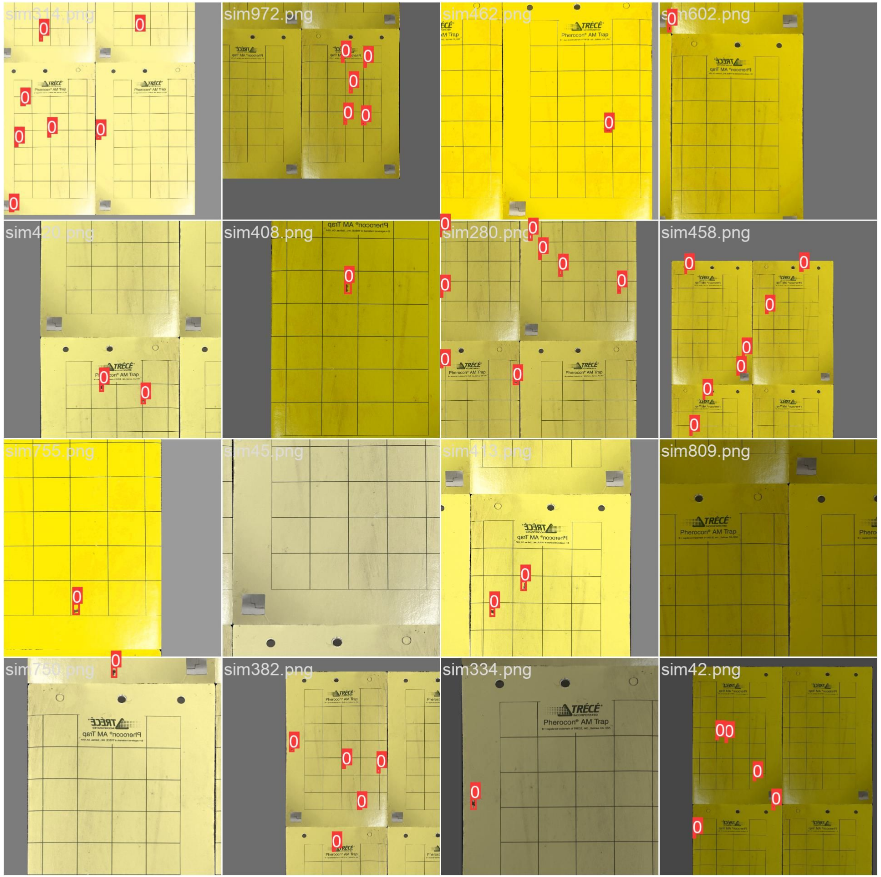
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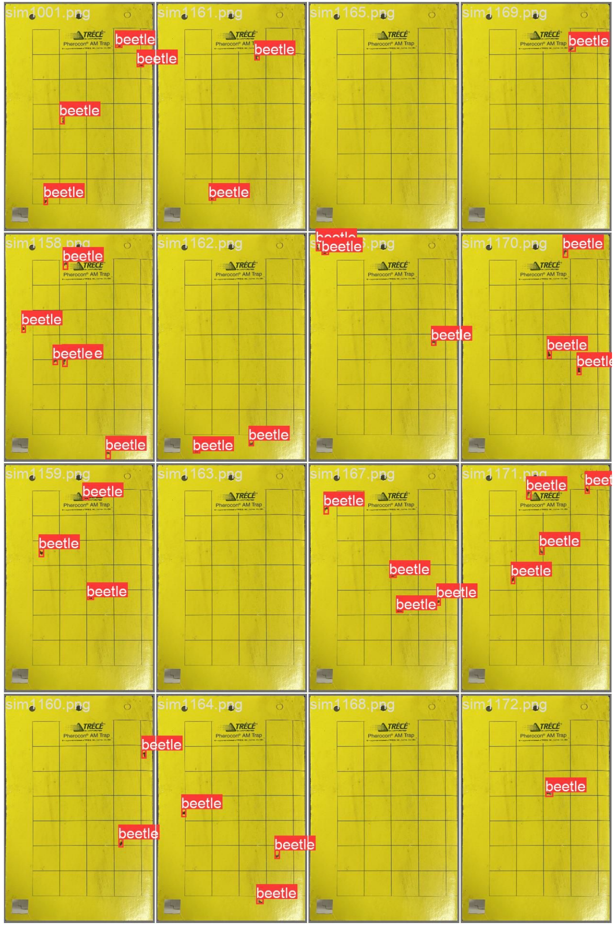
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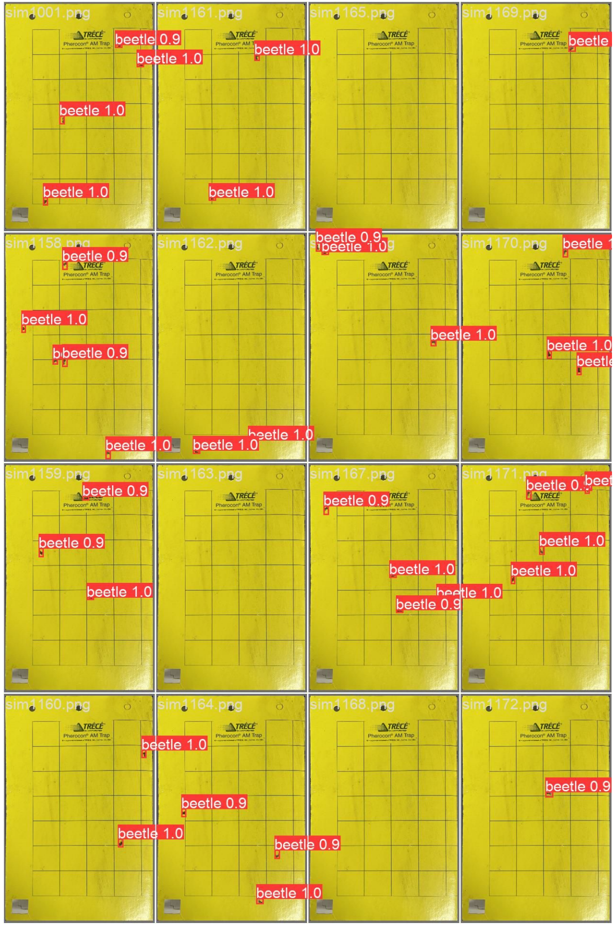
beetle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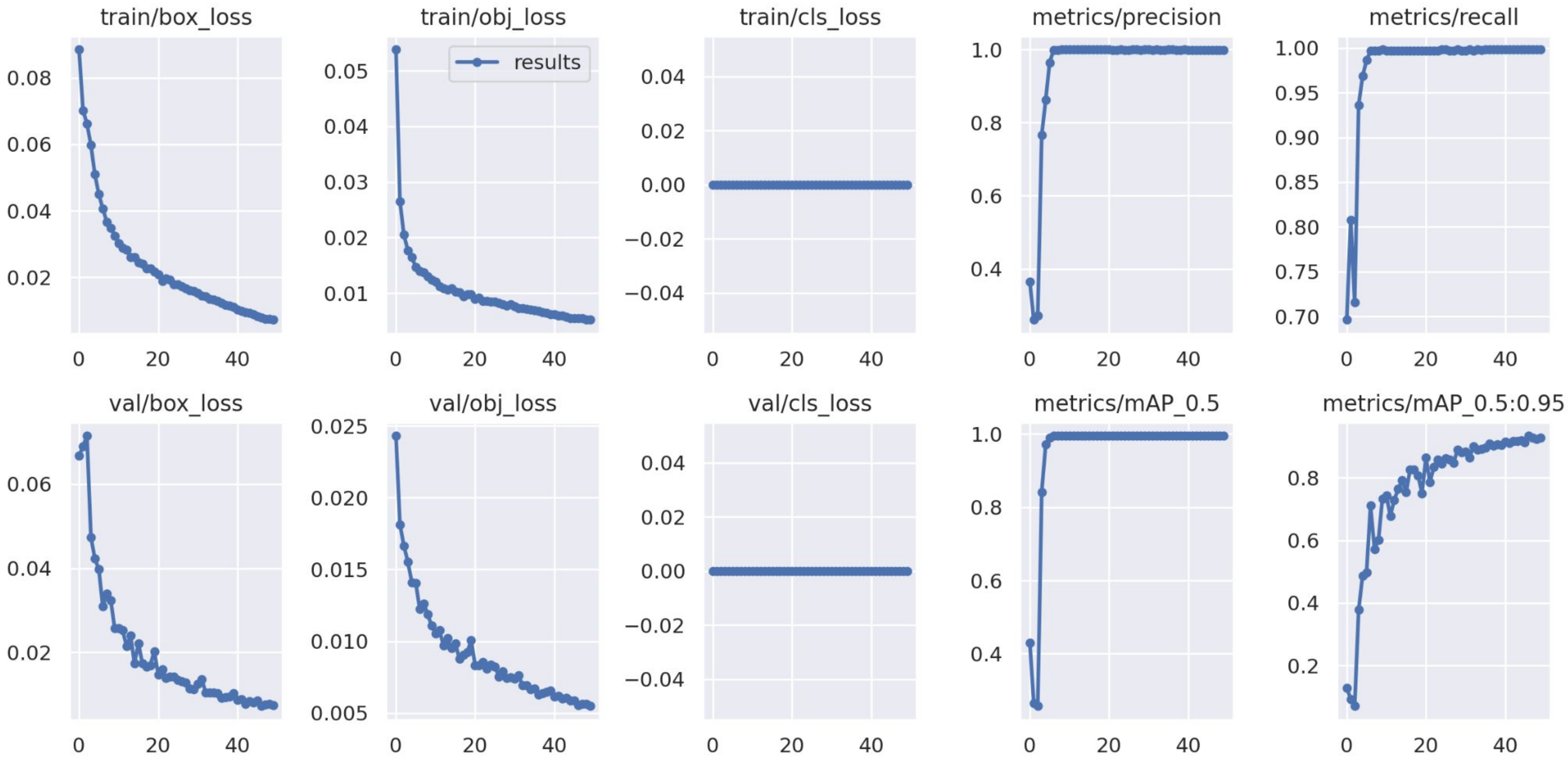
beetle 1.0
beetle 0.9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0.06
0.04
0.02
0
20
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train/obj_loss
results
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0.04
0.03
0.02
0.01
train/cls_loss
0.04
0.02
0.00
−0.02
−0.04
metrics/precision
1.0
0.8
0.6
0.4
metrics/recall
1.00
0.95
0.90
0.85
0.80
0.75
0.70
val/box_loss
0.06
0.04
0.02
val/obj_loss
0.025
0.020
0.015
0.010
0.005
val/cls_loss
0.04
0.02
0.00
−0.02
−0.04
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0.8
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0.4
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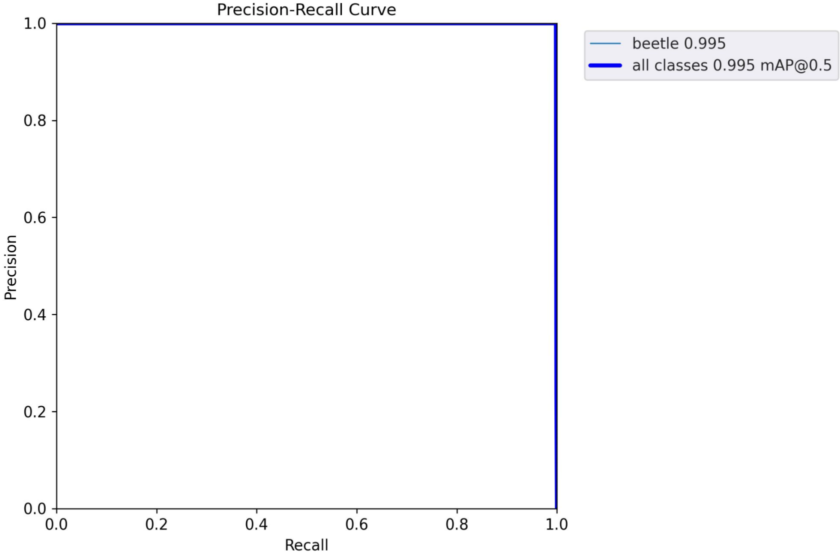
Precision-Recall Curve
Precision
Recall
1.0
0.8
0.6
0.4
0.2
0.0
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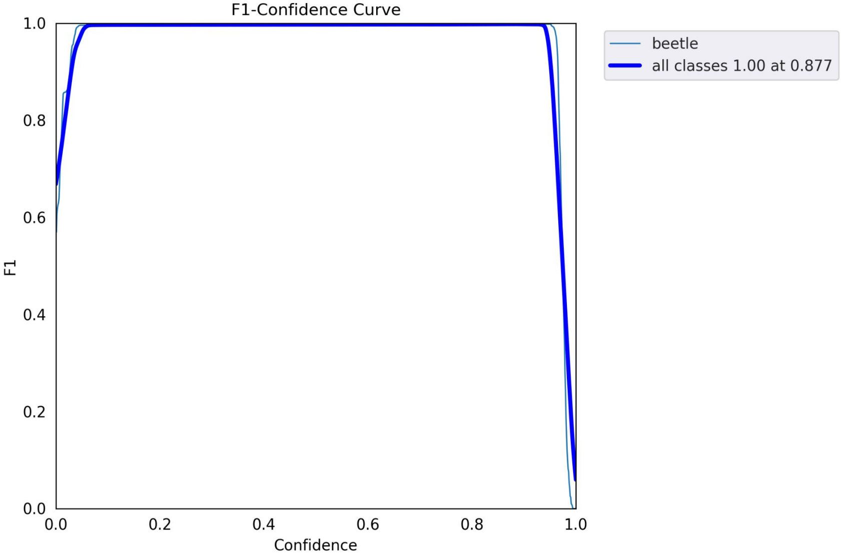
0.6
0.8
1.0
beetle 0.995
all classes 0.995 mAP@0.5


F1-Confidence Curve
F1
Confidence
1.0
0.8
0.6
0.4
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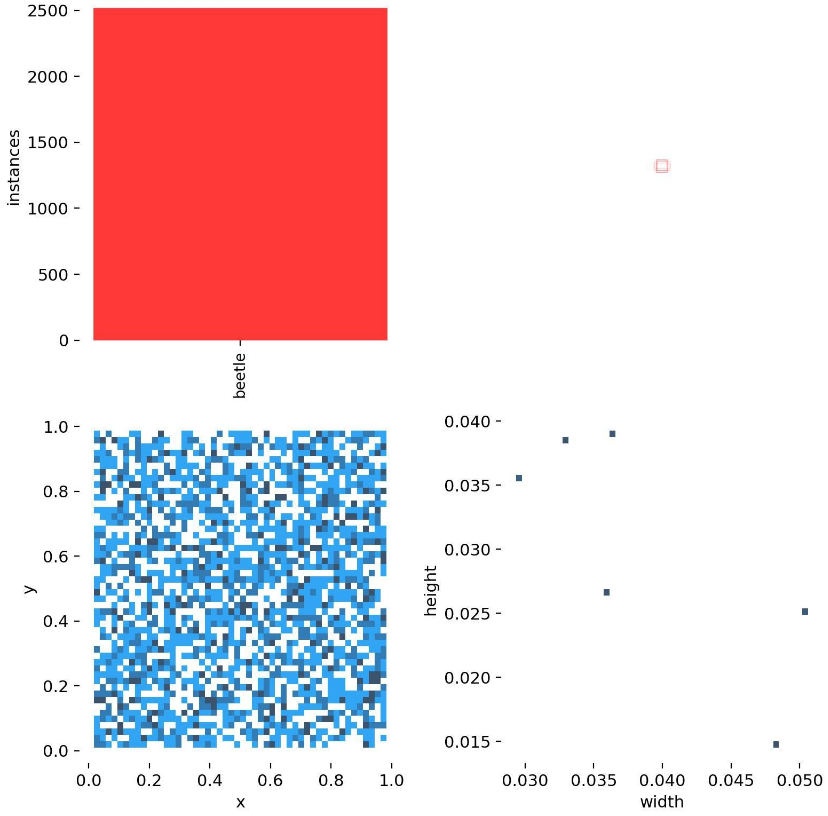
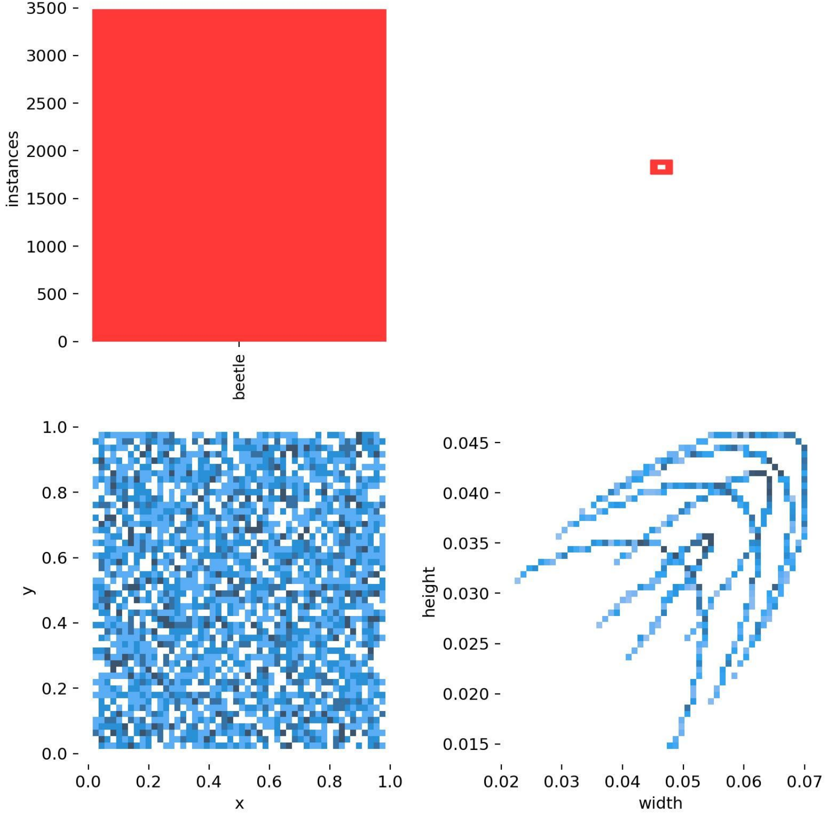
0.8
1.0
beetle
all classes 1.00 at 0.877



instances
2500
2000
1500
1000
500
0
beetle
y
1.0
0.8
0.6
0.4
0.2
0.0
x
0.0
0.2
0.4
0.6
0.8
1.0
height
0.040
0.035
0.030
0.025
0.020
0.015
width
0.030
0.035
0.040
0.045
0.050



instances
3500
3000
2500
2000
1500
1000
500
0
beetle
y
1.0
0.8
0.6
0.4
0.2
0.0
x
0.0
0.2
0.4
0.6
0.8
1.0
height
0.045
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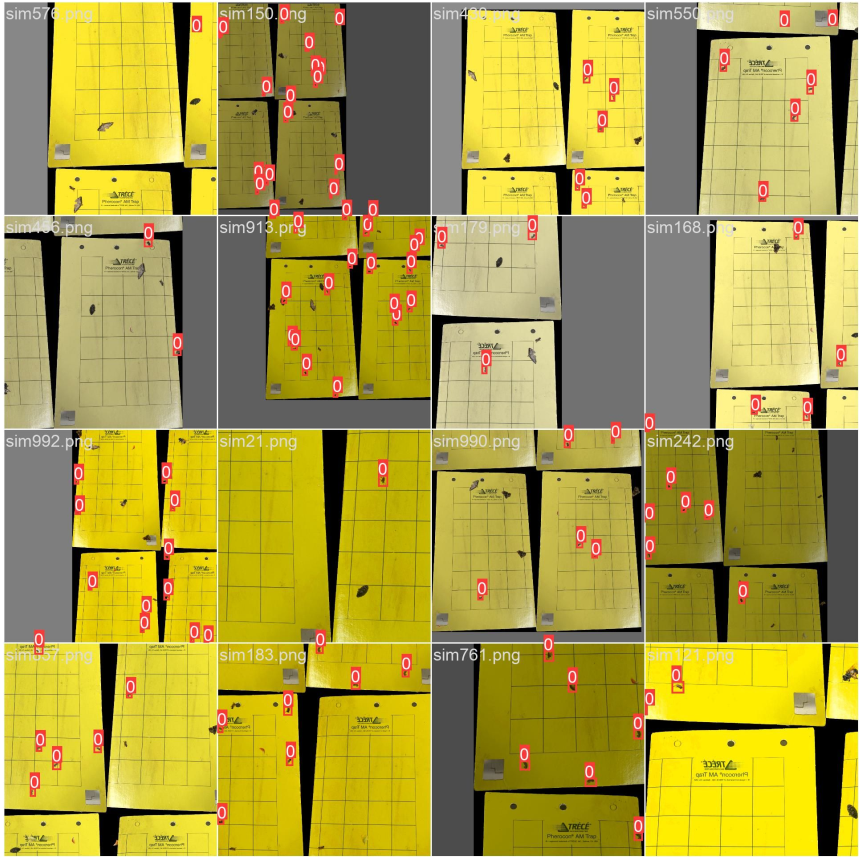
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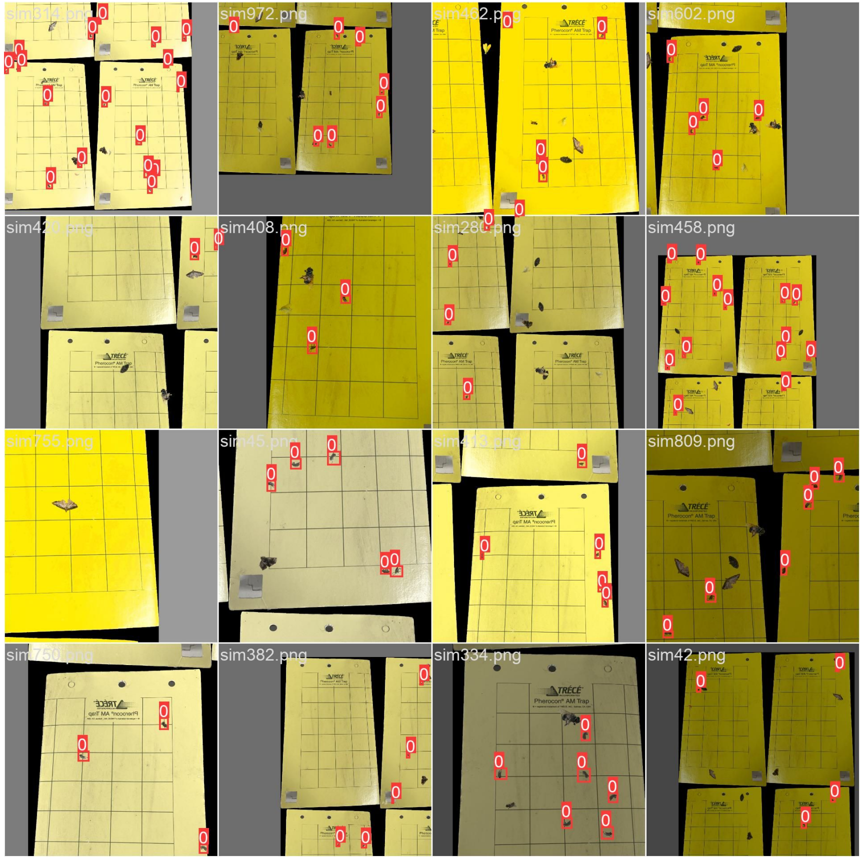
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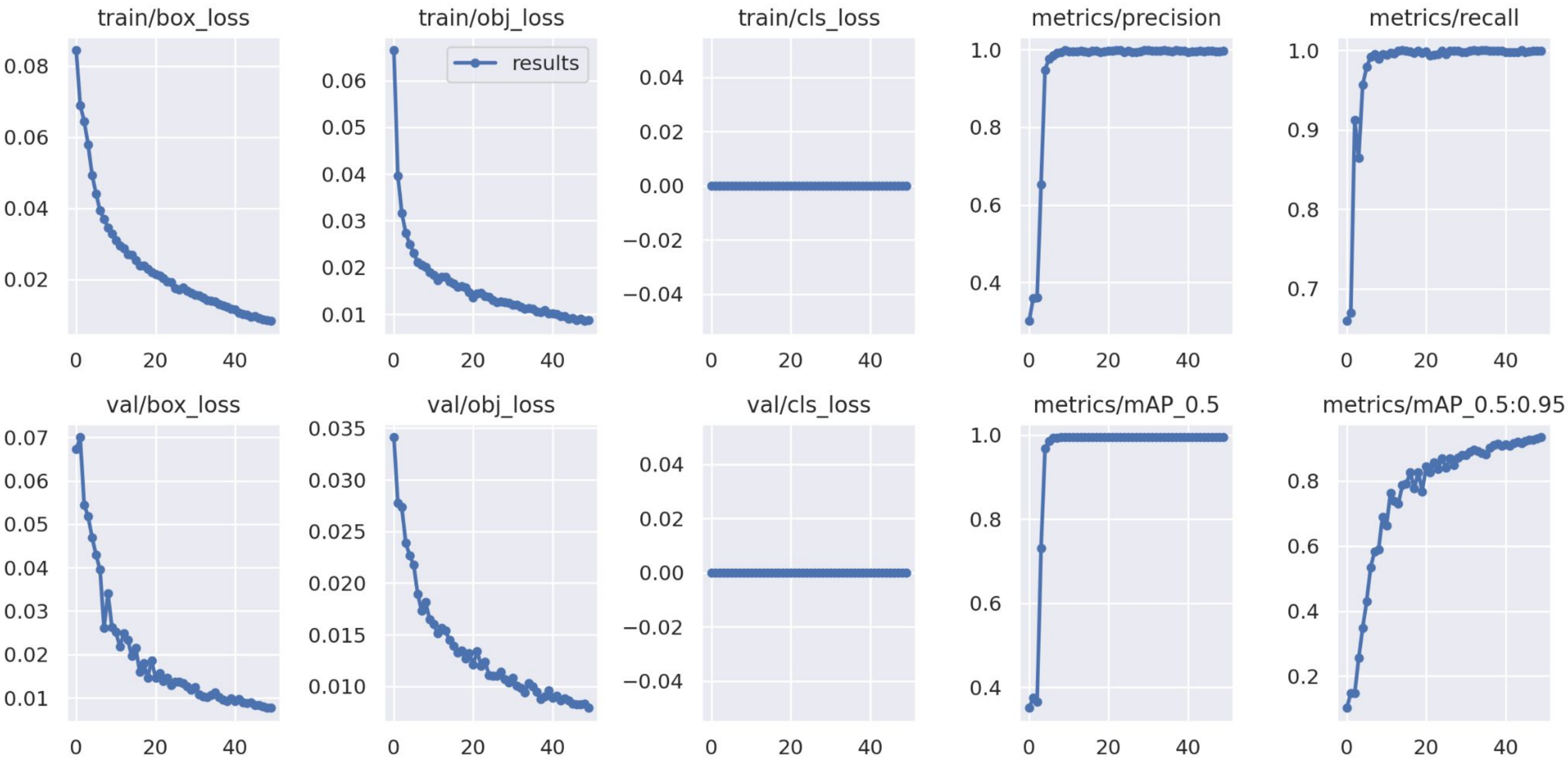
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0.08
0.06
0.04
0.02
0
20
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train/obj_loss
results
0.06
0.05
0.04
0.03
0.02
0.01
0
20
40
train/cls_loss
0.04
0.02
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−0.02
−0.04
0
20
40
metrics/precision
1.0
0.8
0.6
0.4
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20
40
metrics/recall
1.0
0.9
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0.7
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20
40
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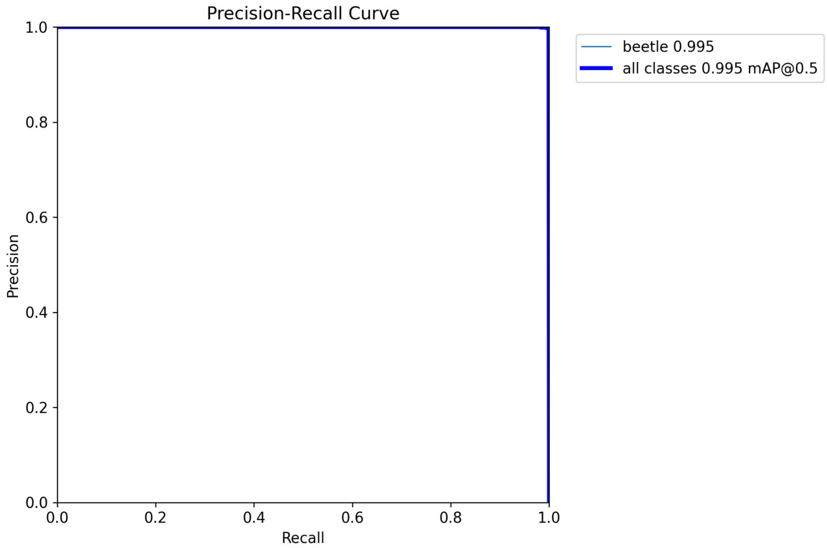
Precision-Recall Curve
Precision
Recall
1.0
0.8
0.6
0.4
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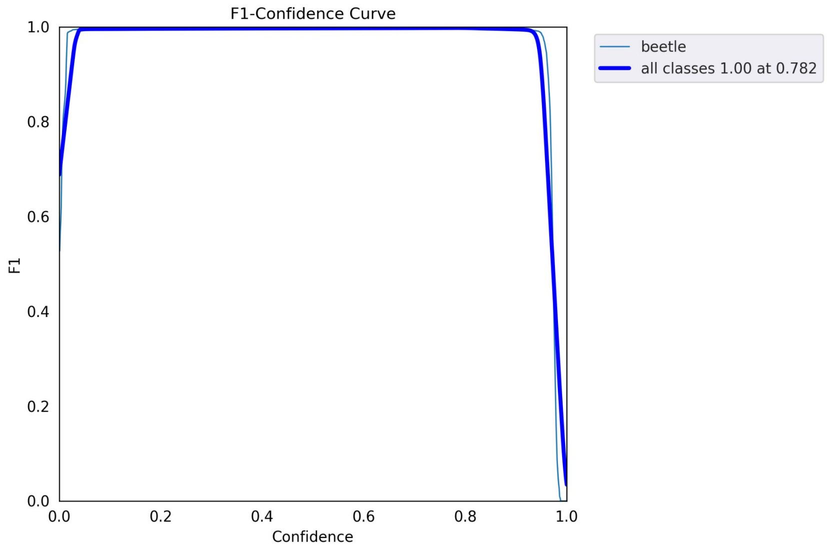
0.8
1.0
beetle 0.995
all classes 0.995 mAP@0.5


F1-Confidence Curve
F1
Confidence
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
beetle
all classes 1.00 at 0.782

sim1001.png
sim1161.png
sim1165.png
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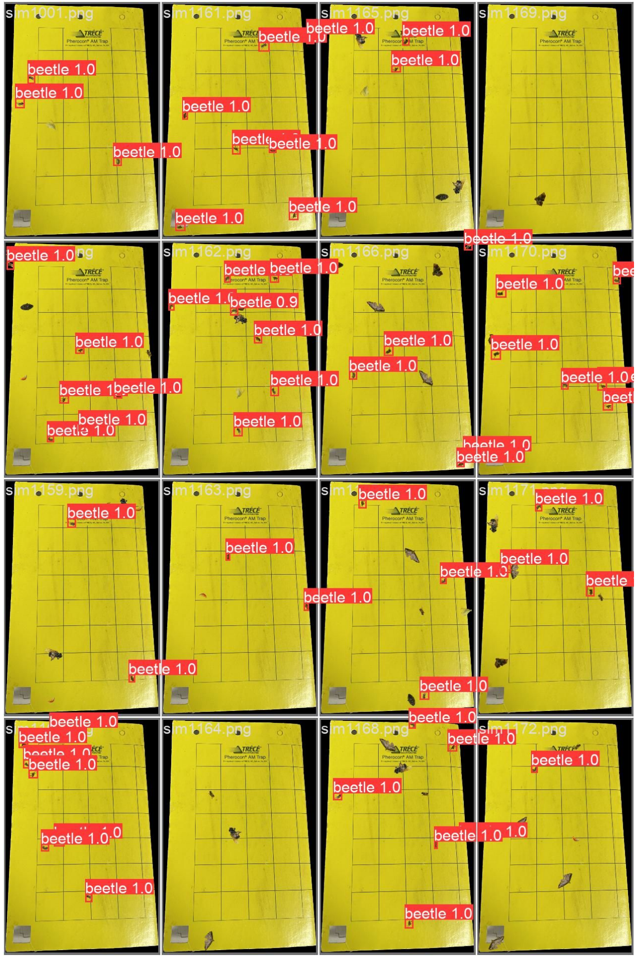
beetle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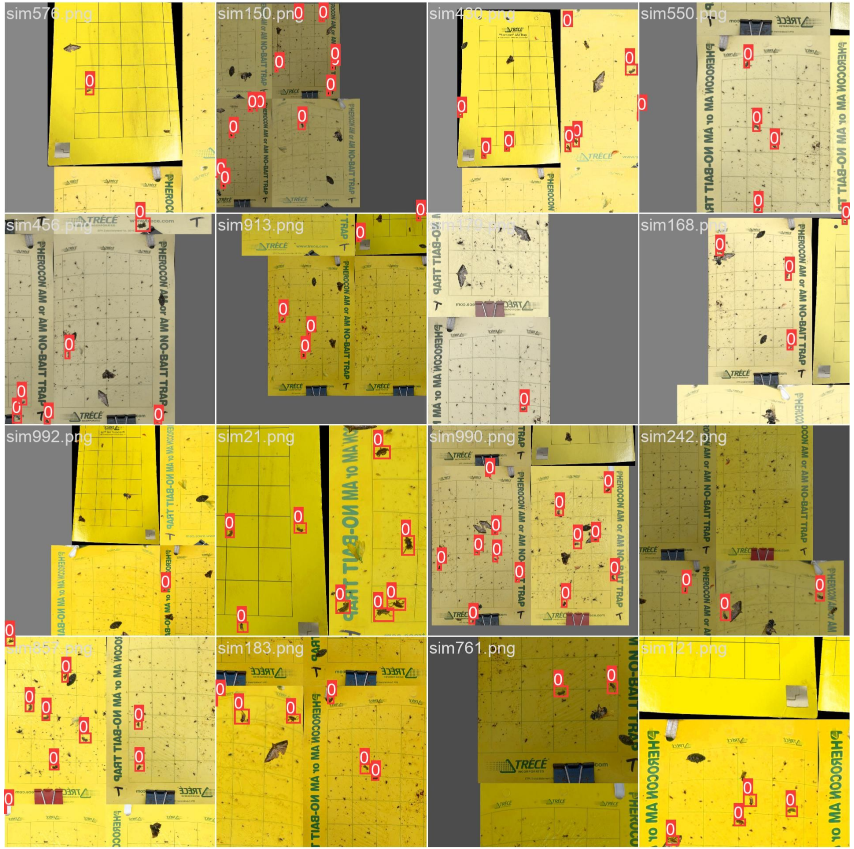
beetle 1.0
beetle 0.9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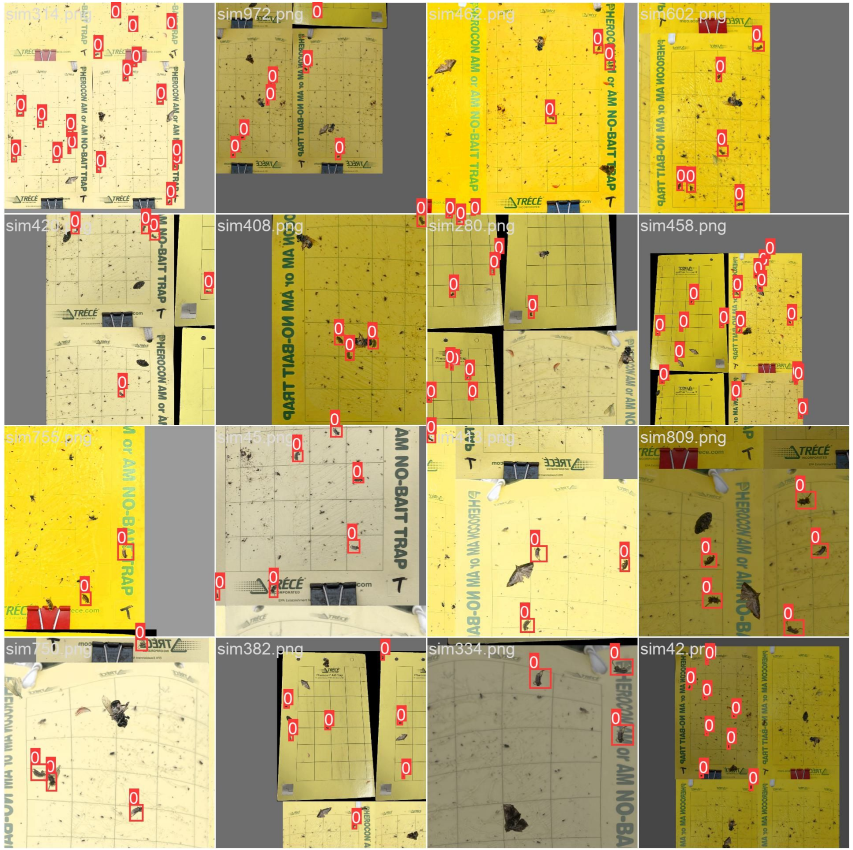
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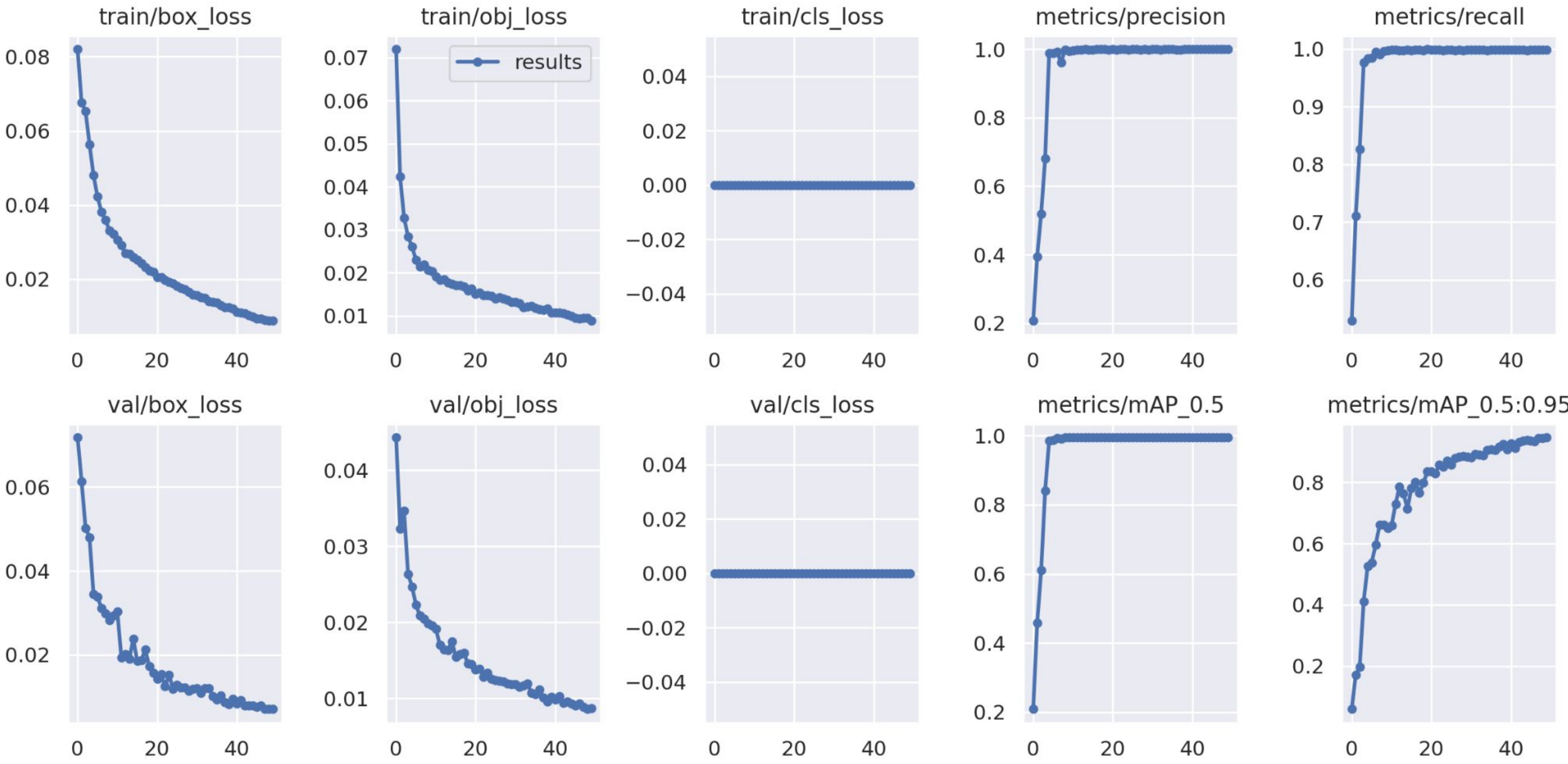
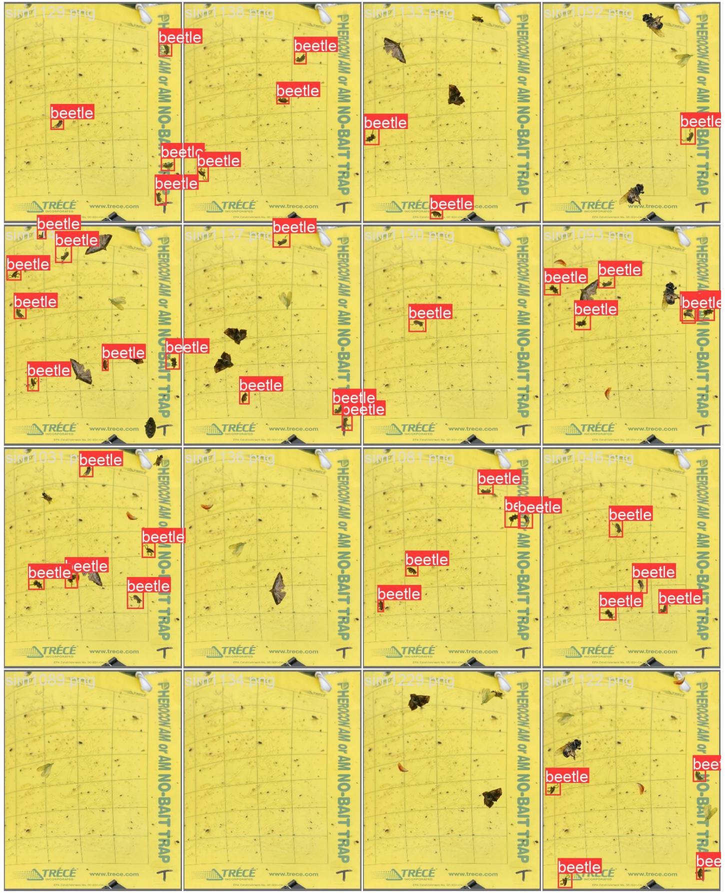
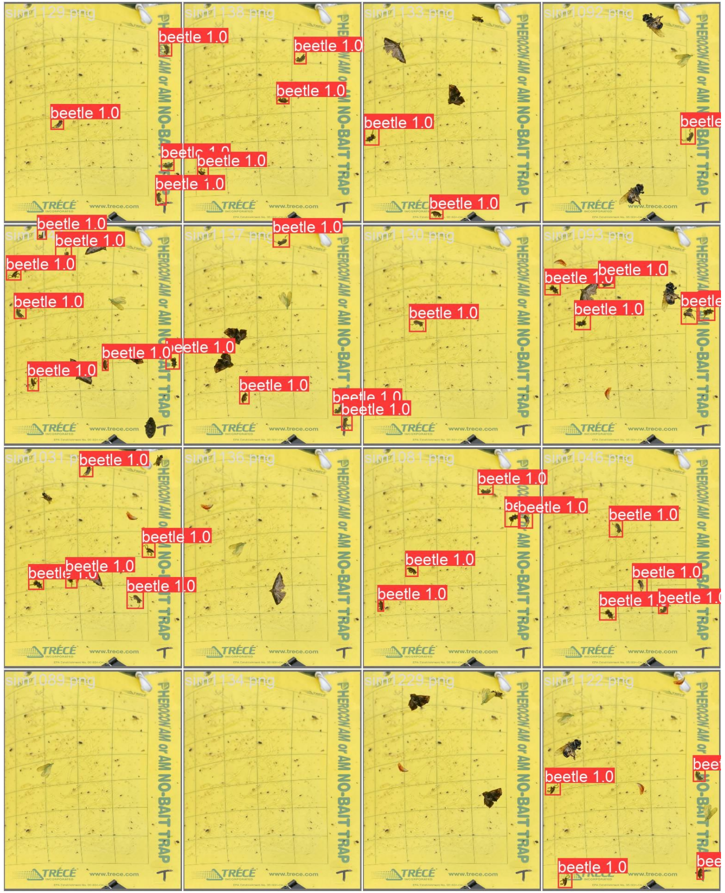
0

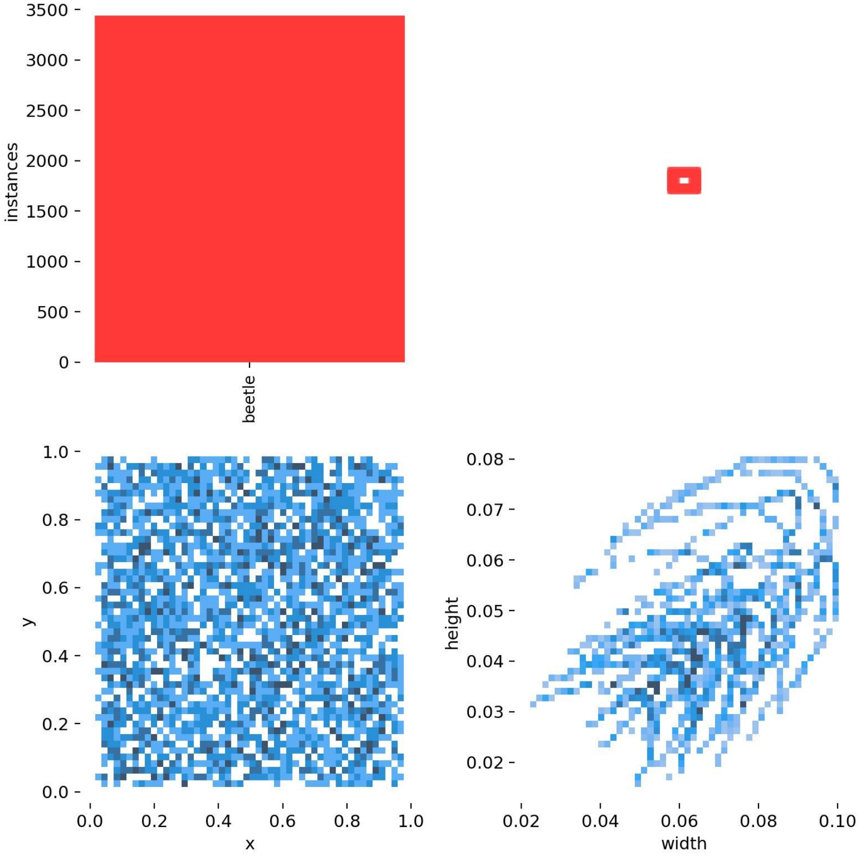

train/box_loss
0.08
0.06
0.04
0.02
0
20
40
train/obj_loss
results
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
20
40
train/cls_loss
0.04
0.02
0.00
−0.02
−0.04
0
20
40
metrics/precision
1.0
0.8
0.6
0.4
0.2
0
20
40
metrics/recall
1.0
0.9
0.8
0.7
0.6
0
20
40
val/box_loss
0.06
0.04
0.02
0
20
40
val/obj_loss
0.04
0.03
0.02
0.01
0
20
40
val/cls_loss
0.04
0.02
0.00
−0.02
−0.04
0
20
40
metrics/mAP_0.5
1.0
0.8
0.6
0.4
0.2
0
20
40
metrics/mAP_0.5:0.95
0.8
0.6
0.4
0.2
0
20
40

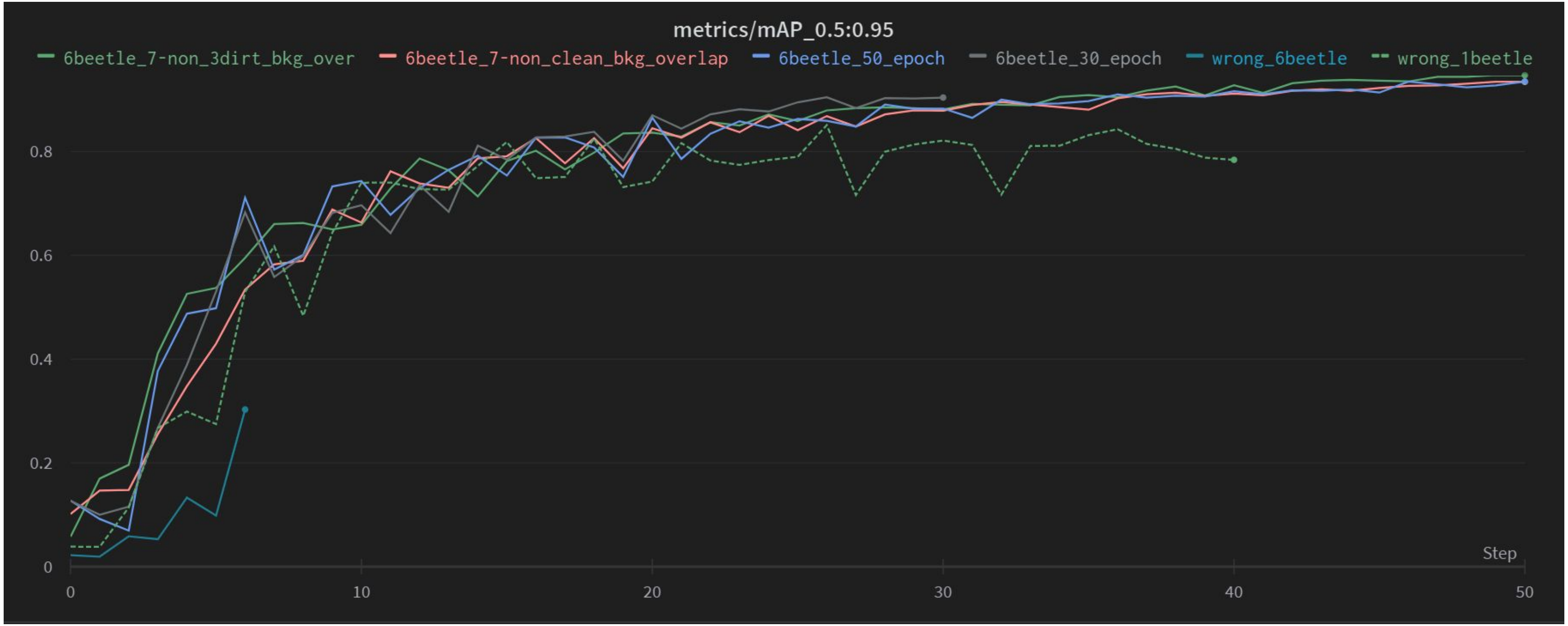


beetle



beetle 1.0


3500
3000
2500
2000
1500
1000
500
0
instances
beetle
1.0
0.8
0.6
0.4
0.2
0.0
y
0.0
0.2
0.4
0.6
0.8
1.0
x
0.08
0.07
0.06
0.05
0.04
0.03
0.02
height
0.02
0.04
0.06
0.08
0.10
width


metrics/mAP_0.5:0.95
6beetle_7-non_3dirt_bkg_over
6beetle_7-non_clean_bkg_overlap
6beetle_50_epoch
6beetle_30_epoch
wrong_6beetle
wrong_1beetle
0.8
0.6
0.4
0.2
0
Step
0
10
20
30
40
50

Next steps

- Use dirtier backgrounds with more noise and observe performance
- Test on real pictures given by Professor Spencer
- Export to TFLite and implement on Arduino
- Test model using images taken from camera

Thank you for listening!